HALF-LIFE MEASUREMENTS

Two characteristics of chemical elements and, in the present instance, of radioisotopes make the precise measurement of radioactive half-lives possible. One is the enormous number of atoms in even the smallest amount of a radioisotope. The other is that, as long as we are able to accurately measure the quantity or amount of a radioisotope, we know precisely how many atoms of that isotope we have.

The latter was the ultimate result of an 1811 hypothesis of an Italian physicist, Avogadro, who postulated that equal volumes of all gases at the same temperature and pressure contained the same number of molecules. It has since been developed that a gram molecular weight of a chemical element—the weight in grams equal to the atomic weight—contains 6.022×10^{23} atoms of that element. The number is known as Avogadro's number and when written out looks like this:

602,200,000,000,000,000,000,<u>000</u>.

We have already learned that the atomic weight of an isotope is equal to the sum of the protons and neutrons in its nucleus. Hence, when we know the weight in grams of a quantity of a radioisotope, we know the number of atoms of the isotope and with the proper equipment can measure the number of atoms decaying per unit time.

For example, the number of atoms in one gram of potassium-40 is equal to:

$$\left(\frac{6.022 \times 10^{23}}{40}\right) = 1.506 \times 10^{22} \text{ atoms}$$

The number of atoms in one gram of uranium-238 is:

$$\left(\frac{6.022 \times 10^{23}}{238}\right) = 2.53 \times 10^{21}$$

All this results in the fact that relatively small amounts of radioisotopes with extremely long half-lives have significant activity. For instance, one gram of thorium-232 with a half-life of 14 billion years has more than 4100 disintegrations per second.

The precise measurement of half-lives requires more sophisticated instruments than the relatively simple instruments that simply detect the presence of radiation, such as a Geiger counter. More sophisticated instruments and techniques can measure precisely the absolute number of alpha, beta, and gamma emissions from a measured amount of a radioactive material.

Half-life measurements: The following are methods for determining half-lives under the given conditions.

1. Radioisotopes with half-lives of several seconds to years:

   Plot the activity of a quantity of the radioisotope as a function of time and determine the time when half has decayed or will decay.

2. Radioisotopes with half-lives below a few seconds:

   a. For gases or solutions containing a known concentration of a radioisotope, flow them past a counter at a known rate. Plot activity versus time.

   b. Attach a solid containing a known quantity of a radioisotope to a rapidly revolving wheel turning at a known rate past a counter. Plot X (counts) versus time.

3. Half-lives less than a second must be measured electronically.

4. Radioisotopes with extremely long half-lives where the rate of decay is essentially constant with time:

   Determine the decay constant. The decay constant is a unique characteristic of each radioisotope and is the fraction of the activity of a quantity of the radioisotope that decays per unit time. It is identified by the lower case of the Greek letter Lambda, λ.

   Know the number of atoms of the radioisotope.

   Count the number of atoms decaying per unit time.

   Then (decay constant) x (number of atoms) = counts/unit time

   $$\text{and decay constant} = \frac{\text{(counts/unit time)}}{\text{(number of atoms)}}$$

   $$\text{but we know: decay constant} = \frac{0.693}{\text{half-life}}$$

   Hence, the half-life in:

   $$\text{seconds} = \frac{0.693\ \text{(number of atoms)}}{\text{(counts/second)}}$$

   $$\text{hours} = \frac{0.693\ \text{(number of atoms)}}{\text{(counts/hour)}}$$

   $$\text{days} = \frac{0.693\ \text{(number of atoms)}}{\text{(counts/day)}}$$

   $$\text{years} = \frac{0.693\ \text{(number of atoms)}}{\text{(counts/year)}}$$

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